Note on Spectral Class and Stellar Colours. By Julia Bell, M.A.

(*Communicated by Professor Karl Pearson, F.R.S.*)

In the *Monthly Notices*, vol. lxvii. pp. 539–42, Mr. W. S. Franks published what is statistically termed a contingency table, showing the dependence of colour on spectral class for 928 northern stars from -25° to N. Pole. The statistical reduction of this table was made by Dr. Alice Lee, and published in a paper on the "Correlation of Stellar Characters," *Monthly Notices*, lxviii. p. 422, by Miss W. Gibson and Professor K. Pearson. The coefficient of mean square contingency was found to be $C_1 = \cdot 74$, thus showing a very considerable measure of relationship between stellar colour and spectral class.

In the last issued *M.N.* (vol. lxviii. p. 673) Mr. Franks provides a further contingency table for northern stars between the same limits of declination, but including nearly four times as many stars, namely 3497. He rightly insists on the close association of the two characters, spectral class and colour class. It will not, I think, be without interest to consider what is the exact numerical measure of this relationship, and whether it is in keeping with the earlier value, as found from a much smaller sample.

Contingency Table for Northern Stars, -25° to N.P.

Colour Class.

Spectral type.	White.	Yellowish-White.	Pale Yellow.	Yellow.	Pale Orange.	Orange.	Orange-Red.	Total.
Bright line Spectra	0 (− ·62)	0 (− ·42)	2 (+ 1·55)	0 (− ·24)	0 (− ·15)	0 (− ·11)	0 (− ·01)	2
Intermediate	5 (+ 1·90)	4 (+ 1·92)	1 (− 1·24)	0 (− 1·18)	0 (− ·78)	0 (− ·56)	0 (− ·07)	10
Orion Type	191 (+116·06)	50 (− ·45)	1 (− 53·11)	0 (− 28·58)	0 (− 18·75)	0 (− 13·49)	0 (− 1·66)	242
Sirius Type	793 (+424·4)	338 (+ 89·93)	59 (−207·11)	0 (−140·54)	0 (− 92·22)	0 (− 66·36)	0 (− 8·17)	1190
α Carinæ Type	78 (+ 56·41)	204 (+113·52)	143 (+ 45·95)	9 (− 42·26)	0 (− 33·63)	0 (− 24·20)	0 (− 2·98)	434
Procyon Type	7 (− 27·37)	47 (+ 23·86)	51 (+ 26·18)	4 (− 9·11)	2 (− 6·60)	0 (− 6·19)	0 (− ·76)	111
Capella Type	9 (−128·51)	69 (− 23·56)	242 (+142·71)	68 (+ 15·56)	41 (+ 6·59)	13 (− 11·76)	2 (− 1·05)	444
Arcturus Type	0 (−245·90)	17 (−148·52)	260 (+ 82·45)	274 (+180·23)	155 (+ 93·47)	84 (+ 39·73)	4 (− 1·45)	794
Aldebaran Type	0 (− 33·76)	0 (− 22·72)	12 (− 12·37)	32 (+ 19·13)	29 (+ 20·55)	36 (+ 29·92)	0 (− ·75)	109
Betelgeuse Type	0 (− 46·45)	0 (− 31·27)	11 (− 22·54)	26 (+ 8·29)	44 (+ 32·38)	59 (+ 50·64)	10 (+ 8·97)	150
19 Piscium Type	0 (− 3·41)	0 (− 2·30)	0 (− 2·46)	0 (− 1·30)	0 (− ·85)	3 (+ 2·39)	8 (+ 7·92)	11
Total	1083	729	782	413	271	195	24	3497

The accompanying table shows Mr. Franks' data, providing by the numbers in brackets the deviations in the observed frequencies from the frequencies which would occur if the two characters were independent. The value of the coefficient of mean square contingency is

$$C_1 = \cdot 756,$$

with a probable error between ·01 and ·02.

Mr. Franks' much larger sample thus entirely confirms the degree of association found from the earlier data, and may serve to give confidence to those who doubt whether the numbers found to express association of characters by modern statistical methods are really characteristic of stellar populations. The wide change in the constitution of the sample has not modified the intensity of dependence within the limits of the probable error of sampling.

One further point: the association here found is essentially one of *qualitative* classes, and it is difficult to imagine a single *quantitative* unit at the basis of either character, *i.e.* we are dealing with a case where contingency and not correlation methods must be adopted. (*M.N.*, vol. lxviii. p. 417) If, for a moment, we could suppose two *correlated* variables following the Gaussian law of frequency behind both colour class and spectral type, we should be rudely awakened to the absurdity of the hypothesis by noting that the coefficient of mean contingency* for this table is

$$C_2 = \cdot 86,$$

and the equality $C_1 = C_2$ necessitated by the above hypothesis is wholly unfulfilled.

The purpose of this note is to emphasise two points:—

(1) The stability of statistical constants when drawn from different samples of the stellar population.

(2) The need for remembering, in applying modern statistical methods to astronomical problems, that correlation is only a single and not very long chapter in the complete theory of association: the chapter on contingency may often be of greater service.

* "On the Theory of Contingency and its relation to Association and Normal Correlation," by K. Pearson, *Drapers' Research Memoirs*, Dulau & Co., 1904.

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Note on some Photographic Images of Mars taken in 1907 *by Professor Lowell.* By E. M. Antoniadi. (Plate 4.)

Some time ago Professor Percival Lowell, Director of the Flagstaff Observatory in Arizona (U.S.A.), had kindly sent to Mr. A. C. D. Crommelin a print showing 40 splendid images of Mars, taken by him on 1907 July 11, with various exposures, the mean longitude of the centre of the disk being nearly 250° at the time.

This print was handed on to me by Mr. Crommelin.

The amount of detail shown on these photographs is very considerable, and I have deemed it worth the while to submit these images to a thorough examination, and to group the various features shown on a large scale drawing. I have also decided to show no marking, traces of which could not be found on more than one image.

The fair publication of such a drawing is by no means an easy matter,—first, owing to the diffuse limits of the dusky spots, and to the very delicate gradations of the shading rendering interpretation exceedingly difficult; and secondly, owing to obstacles attending reproduction. The latter, however, can be avoided to a large extent by distrusting continuous grey shading, whose reproduction necessitates retouching on the part of the photographic engraver, and by boldly decomposing the duskiness into very small black dots and lines on a white ground. Upon a careful comparison with the originals, fig. 1, Plate 4, will be found satisfactory, as following closely the general appearance of the disk, except in the diffuseness of the limb and in the protrusion of white spots in its vicinity.

My observations of these photographs may be given as follows:—

(*a*) *Varying sharpness and appearance of the markings.*—Owing to atmospheric tremors, the 40 images differ widely in the amount of detail recorded. In addition to this, the self-same marking presents itself under varying forms. The two lakes at each end of the canal called *Cerberus*, for instance, are quite large, dark, and distinct on some images, while on others they are quite indistinguishable from the *Cerberus* mass. What at times appeared as a perfect dumb-bell was a few moments later distorted into a streak. This is a very instructive and *à priori* incredible fact, and one, too, which accounts for the greatly differing representations of the same object by different observers, or for the variety of sensations experienced by single observers on a given night.

(*b*) *The albedo of the limb.*—Another most interesting fact revealed by the photographs is that the superior brightness of the limb, which is so striking a feature in visual observations, especially under low powers, is entirely non-existent. The phenomenon is thus proved to be due to fatigue of the eye and to contrast,* so that the atmospheric layer above the visible markings of the

* *Memoirs B.A.A.*, vol. x., part iii., p. 138.

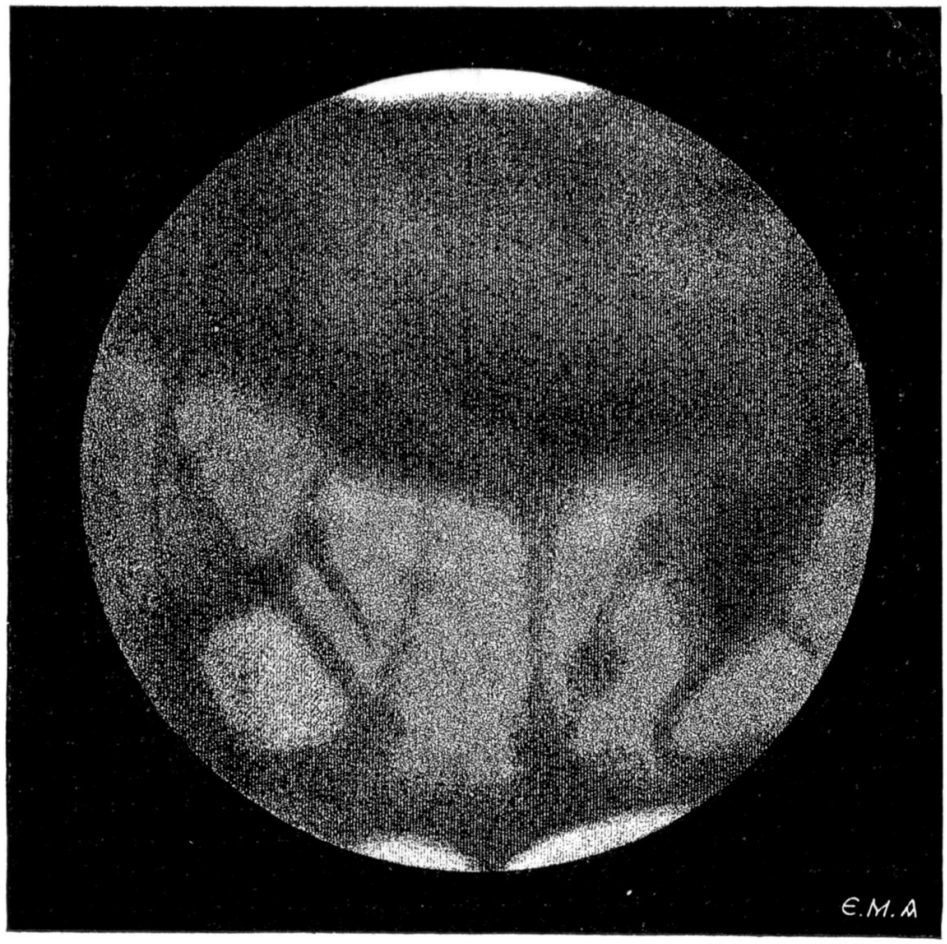

FIG. 1.—Drawing of Mars, showing all trustworthy details visible on photographs of the planet taken by Prof. Lowell on 1907 July 11. $\omega = 250°$.

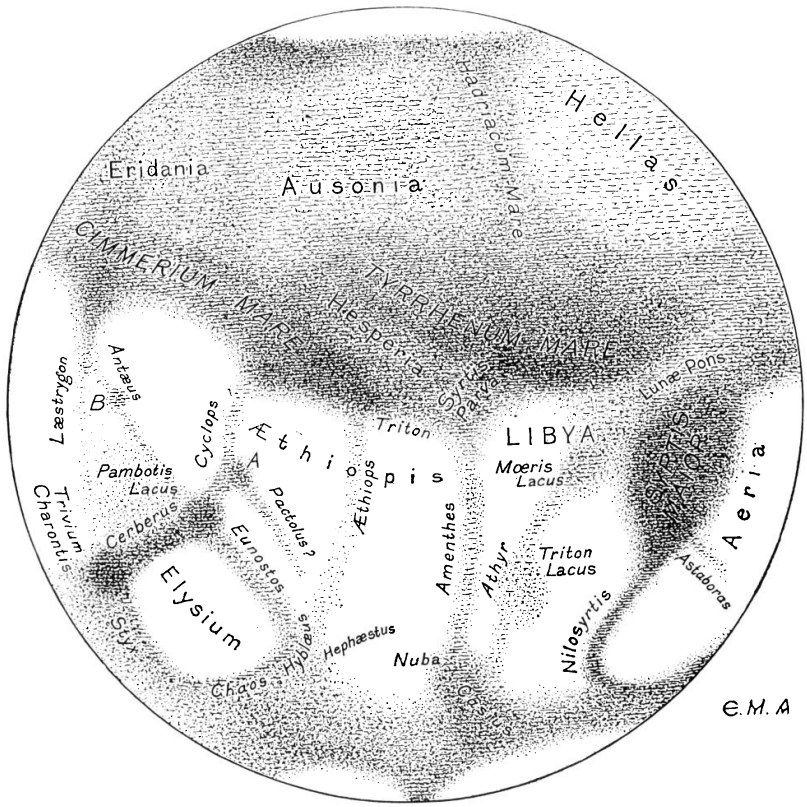

FIG. 2.—Key-chart.